Analysis of fine-grained Dark Material in Martian Craters using HRSC- and OMEGA-Data

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Introduction

As a result of aeolian processes a fine-grained dark material can be found all over the Martian surface. It is characterized by a lower albedo than the surrounding terrain. On crater floors it is often accumulated in large dune-like bedforms. In higher resolution images it can be seen that these intracrater features resolve into distinct dune fields [1] (Fig. 1). A comparison with the global wind fields shows that a coherency between the locations of the material on the crater floors and the main wind direction is not always apparent. In some cases the material is identified as a result of a mechanical weathering of dark layers located in the crater walls, which were cut by the impact. The low albedo and the selective mobility of these materials indicate fundamental differences in composition, physical material properties and origin with respect to the surrounding. For this analysis 44 impact craters with dune fields and other occurrences of dark material were selected (Fig. 2).

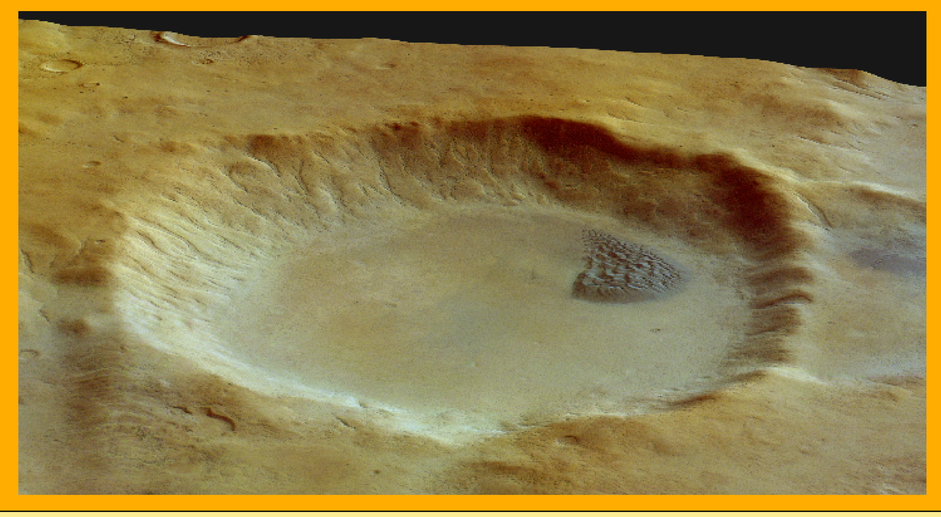


Fig.1: Dunefield in a crater near Argyre Planitia (ESA, DLR, FUB)

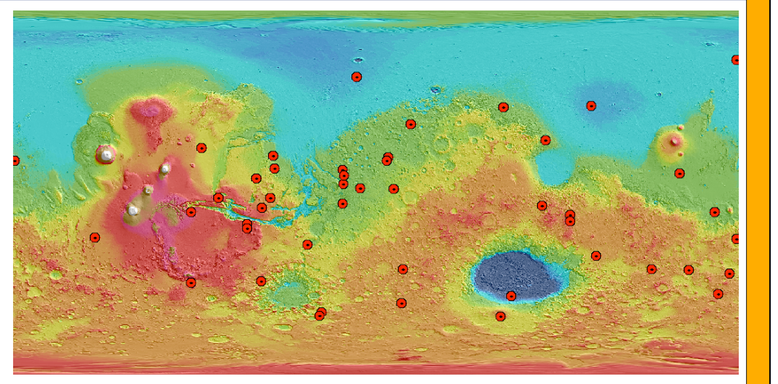


Fig. 2: Global overview of the 44 selected craters (background: MOLA DTM (DLR, ESA, FUB))

Comparison with the global wind fields

Mobile dunes are built and shifted by the actual wind fields. If the dune orientation does not coincide with the actual wind fields, the dunes are fossil. Therefore a comparison was made between the actual wind fields and the main orientation of the dune formation. The latter was derived from the dune shape (Fig. 3) and wind streakes. For the actual wind directions a modelled wind field from the Mars Climate Database (MCD) by the LMD [2] was used (Fig. 4). For these comparison only HRSC orbits recorded at the the same season N-winter/S-summer were used.

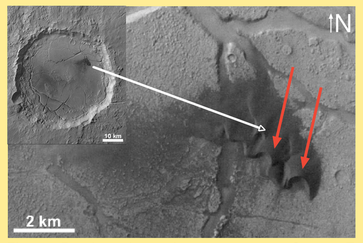


Fig. 3: Barchan dunes in a crater at 5°S, 344°E (Mars Express HRSC image, ESA/DLR/FUB). (red arrows: main wind direction derived from the dune shape)

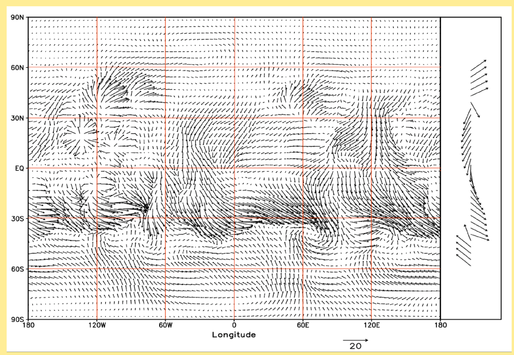


Fig. 4: Global wind fields for Ls: 270° - 300° (Mars Climate Database, LMD [2]).

Some of the dune fields show a good correlation with the actual wind fields (Fig. 5a, 5b). Thus they might still be active shifted. But others show different wind directions than the actual wind field (Fig. 6a, 6b), indicating fossil forms. 19 of the 44 examined dune fields seem to be fossil.

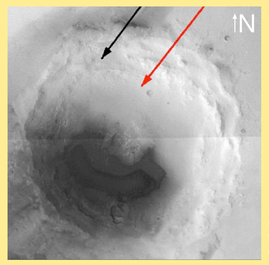


Fig. 5a: Correlative wind directions in a crater at 9°N, 150°E. (Ls: 335.77°)

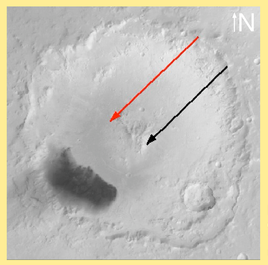


Fig. 5b: Correlative wind directions in a crater at 15°N, 181°E. (Ls: 282,36 °)

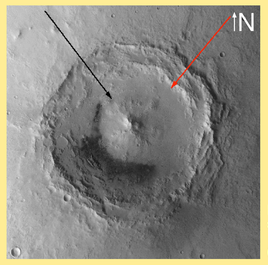


Fig. 6a: Different wind directions in a crater at 10°N, 167°E. (Ls: 273.24°)

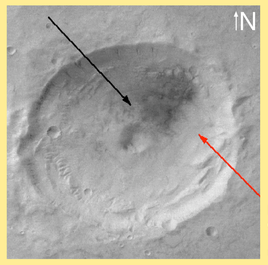


Fig. 6b: Different wind directions in a crater at 11°N, 343.5°E. (Ls: 334.14°)

(red arrows: main wind direction derived from the dune shape, black arrows: main wind direction of the MCD wind field)

Dark material in craters

The dark material in impact craters can be found on both Martian hemispheres, indicating that this material is distributed all over Mars by aeolian processes, whereas the craters act as trap (Fig. 7). Some of dark material fields show evidence for such an allochtonous distribution process by thin layers of dark material outside the crater (Fig. 8 & 9).

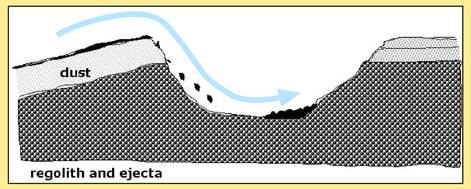


Fig. 7: Sketch of a crater acting as a trap for windblown material.

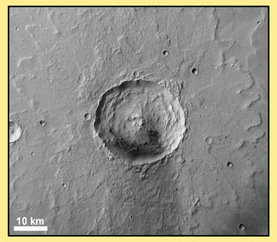


Fig. 8: Dune field in a crater at 11°N, 343°E with a thin streak of dark material south of the crater (Mars Express HRSC image, ESA/DLR/FUB).

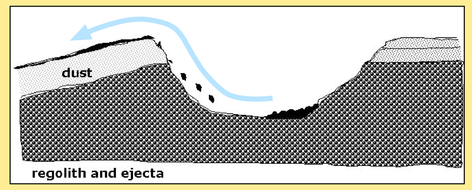
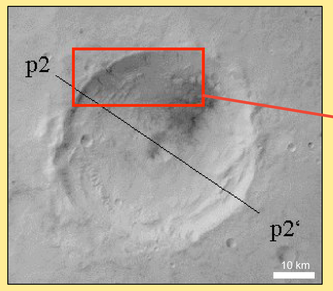


Fig. 9: Sketch of a crater showing an allochtonuous characteristic of dark material.

However, some of the craters with dark materials on their floors do not have dark material outside the crater but have dark outcrops and dark streaks that run downslope (Fig. 10), which suggests the dark material to be the result of weathering and erosion of dark layers cut by the impact.



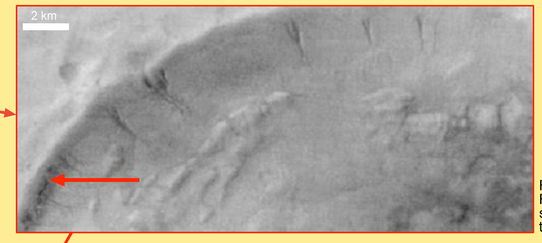


Fig. 10: HRSC image of the crater of Figure 6a and a zoom image which shows a thin layer of dark material in the crater wall (ESA/DLR/FUB).

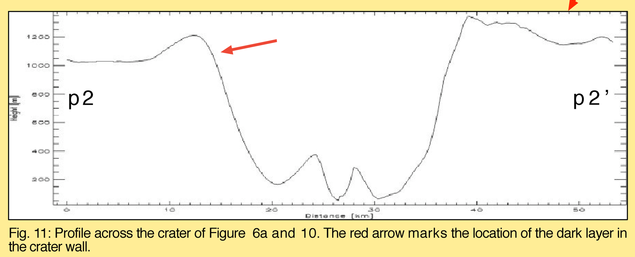


Fig. 11: Profile across the crater of Figure 6a and 10. The red arrow marks the location of the dark layer in the crater wall.

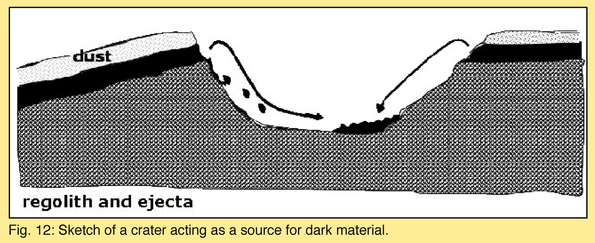
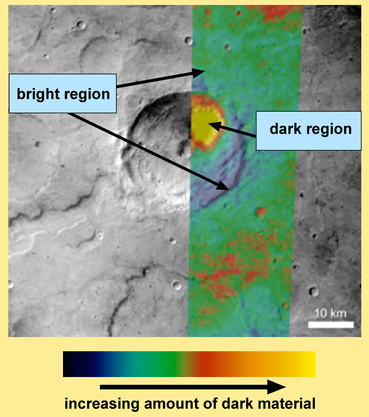


Fig. 12: Sketch of a crater acting as a source for dark material.

Composition of dark material

The significant lower albedo of the dark material suggests not only differences in particle size but also compositional differences with respect to the surrounding materials. The dark material seems to be unoxidized and thus should have a strong mafic component. Spectra in the near infrared from the Mars Express OMEGA instrument [6] indicate a higher content of unweathered mafic minerals such as high Ca-pyroxenes (HCP), low Ca-pyroxenes (LCP) and olivine (OL) (Fig. 12 & 13).



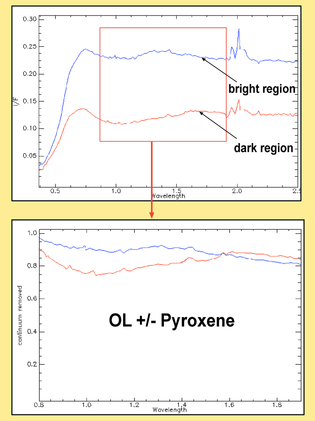
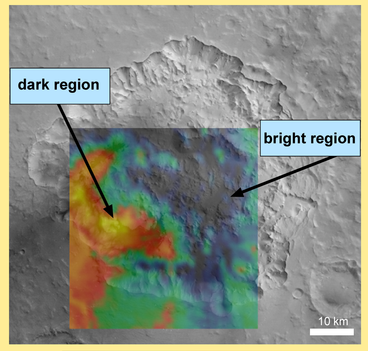


Fig. 12: Distribution of dark material in a crater at 39°S, 174°E and its spectral characteristics (red spectrum) compared to the surrounding terrain (blue spectrum) based on Mars Express OMEGA data (ESA/DLR/FUB/CNES/IAS).



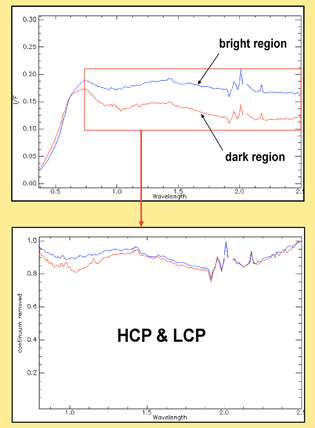


Fig. 13: Distribution of dark material in a crater at 3°S, 307°E and its spectral characteristics (red spectrum) compared to the surrounding terrain (blue spectrum) based on Mars Express OMEGA data (ESA/DLR/FUB/CNES/IAS).

Conclusions

The intracrater materials on Mars were built by aolian processes but not every dune field is effected by the actual wind fields. The dark material is of mafic composition comprising a higher amount of pyroxene and olivine than the surrounding rocks and dust. This large constituent of mafic minerals indicates little or no chemical weathering. This leads to the assumption that the material could not have been located at the Martain surface during times, when liquid water existed on Mars. This could indicate recent erosion and distribution all over Mars. Alternatively the material could be old and conditions for chemical weathering have not existed on Mars since Hesperian times.

References:
[1] Edgett & Christensen (1994): JGR 99, E1, 1997-2018.
[2] Lewis et al. (1999): JGR 104, E10, 177-194.
[3] Bibring et al. (2004): ESA SP 1240, 37-49.